Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 6(3): 156- 165
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jeteas.scholarlinkresearch.com

Climate Change Impact on Infrastructure in Osogbo Metropolis, South-West Nigeria

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Abstract

This research aims at analyzing the variability of rainfall over Osogbo between 1960-2010 and the associated impact on the design of road projects within Osun State. While Mann Kendall analyses showed a positive trend in annual rainfall, ANOVA tests showed that the inter-annual variability of rainfall was not statistically significant. Rainfall variability of 15.6% was obtained for the study area while the mean annual Standardized Precipitation Index value of -0.1198 indicated that the inter-annual variation of rainfall was near normal. In terms of coefficient of variation, monthly rainfall was majorly seasonal and slightly moderately seasonal, with the highest and least coefficient of variations of 3.81 and 0.30 obtained in April and June respectively. The significance of this research was that it was able to reveal both increasing monthly rainfalls as well as increasing mean decadal annual rainfall in the study area. Furthermore, hydrologic modelling of runoff from Osogbo watersheds revealed that out of the seven culverts that were investigated, four were grossly inadequate which require upgrade while the remaining three culverts require regular desilting maintenance. The potential benefit of this research is that it has revealed that utilization of non-certified professionals by the State Government in the design and execution of road and drainage projects often leads to ill-conceived and poorly executed projects which does not justify the huge expenditure on such projects and further exposes the populace to more catastrophic flooding incidences. Engagement of certified engineering professionals in the design, construction and supervision of road and drainage projects guarantees best value for money. In addition, it is recommended that rainfall variability and climate change impacts must be factored in the design of drainage systems in order to increase their resilience to climate variability and the associated negative impacts such as flooding.

Keywords: climate change; culvert capacities; rainfall variability, hydrologic and hydraulic analyses

INTRODUCTION

Infrastructures are capital assets that contribute to a productive economy (EC, 2013) and include transportation which include road, rail, air and water transport, energy, communications, water, waste management, health, financial and social infrastructures. Their interdependencies makes it imperative to improve the resilience of our infrastructure which are often capital intensive.

The severity of climate impacts on infrastructures varies from one location to another according to existing adaptive capacity and resilience. Adapting infrastructures requires site-based analysis of hydrological trends and impact patterns (Kundewicz, 2013).

Often times in Nigeria, large-scale infrastructure projects do not sufficiently take into consideration the long-term impacts and potential risks involved throughout the lifetime of such projects. Likewise, professionals and stakeholder engagement is not adequately facilitated to enhance the decision-making process, a situation which often results in execution of ill-conceived projects which further increases the risk of maladaptation.

Doll et al (2013) recommends a risk approach to climate change through multi-model studies while Andersson-Skold et al (2014) recommends engagement of professionals and non-professionals stakeholders in developing a decision support tool to aid government in appropriate city planning and infrastructure projects. Collaborative, anticipatory and adaptive governance was advocated by Kininmonth et al (2015) while Hess et al (2013) solicited recognition of variability and unpredictability and inclusion of resilience in pro-active development of towns and cities.

In order to avoid future negative externalities, EC (2013) recommended that infrastructure projects must incorporate detailed local assessment of local climate impacts which reduces the margin of error and decreases inefficiency of infrastructural projects arising from under- or over-designed projects with attendant environmental costs. In changing climate scenarios, it is increasingly important that infrastructure with design life greater than 20 years be designed to be resilient with past, present and future climatic conditions in order to minimize climate risks to road infrastructure from road flooding and pavement deterioration.

STATEMENT OF THE PROBLEM

Residents of Osogbo experience incessant flooding which was attributed to high intensity short-duration rainfalls. During heavy storms, the floods overflow to the roads, affecting vehicular and pedestrian traffic and endanger the lives of people within Osogbo. The roads infrastructure get submerged at culvert locations thus leading to gradual deterioration of the pavement structure. Mitigative efforts adopted by the State Government to address these challenges have proved abortive including destruction of residential houses and commercial buildings perceived to be blocking runoff drainage as well as construction of new culverts without carrying out necessary hydrologic/hydraulic analyses to properly estimate actual expected runoff volumes due to climate change impacts. Therefore, this study attempts to ascertain the root causes of the incessant flooding and recommend appropriate solutions.

AIM AND OBJECTIVES OF STUDY

The aim of this study is to analyze the climate variability of rainfall over Osogbo between 1960-2010 and the associated impact on highway culvert capacities within the State. The objectives of this research are:

- To assess the rainfall trend and variability in the study area within the last fifty years.
- Evaluate the impacts and implications of rainfall variability on the design of road projects within the State in order to improve resilience and durability of highway infrastructure.
- Perform hydrologic modeling of Osogbo runoffs at existing culvert locations
- Perform hydraulic modeling of culverts to determine existing capacities and optimal upgrade capacities to contain 100-year peak flows
- Recommend upgrade culvert geometries where necessary.

MATERIALS AND METHODS

Study Area

Osogbo, the capital of Osun State, is located on latitude 7.7667° and longitude 4.5667° in Southwest of Nigeria (Figure 1). It has a population density of 350-500 persons/m^2. Osogbo is characterized by Guinea Savannah climate with annual rainfall range of 1100-1500mm (Figure 2). The population of Osogbo grew from 106,386 to 155, 507 between 1991- 2006 (NBS, 2010). In line with Vision 20:2020, the Osun State Government embarked on provision of physical infrastructures within the State which includes rehabilitation and construction of new roads/highways as well as drainage facilities which was expected to curb incessant flooding experienced in the State (Figure 3)

Figure 1 Map of Nigeria Showing Osun State (Fadare and Olawuni, 2008)

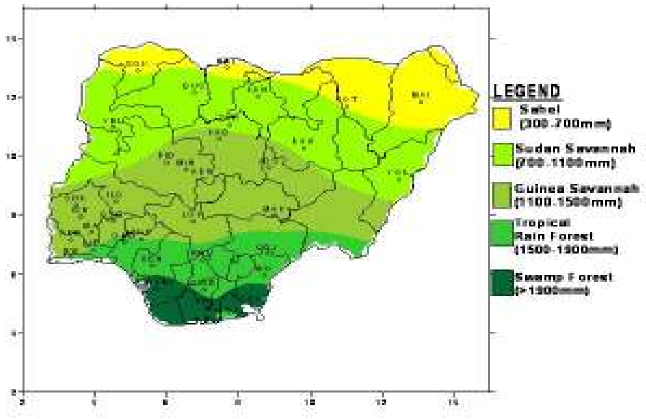

Figure 2. Map of Nigeria showing the climatic zones

Figures 3 (a) and (b) Undersized Rasco culvert being submerged during storms of October/November, 2013

Figure 4 Undersized culverts at (a) Alakewudo (Sawmill) (b) Rasco Hall

Rainfall Data

The meteorological data used in this study were monthly precipitations spanning a period of fifty years (1960-2010) for Osogbo. The data were sourced from the archive of Nigerian Meteorological Agency (NIMET) in Oshodi, Lagos State.

Mann-Kendall Trend Analysis

The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The major benefit of this test was that the data need not conform to any particular distribution. The data values were evaluated as an ordered time series and each data value were compared to all subsequent data values.

Standardized Precipitation Index

Standardized precipitation index (SPI) is a statistical tool used to depict the fluctuation exhibited by the hydro-meteorological parameters. SPI have been effective for rainfall variability analysis in the Niger basin area (Babatolu, 1998), calculating climate change impact on water resources and adaptation strategies in the Sudano-Sahelian Ecological Zone (SSEZ) of Nigeria (Ojoye, 2012) and was used to investigate the variability of annual precipitation in western Iran (Raziel, 2008). Equation 1 (Akinsanola and Ogunjobi, 2014) was used to examine the SPI of the rainfall data for the study area.

$$\mathrm{SPI} = \frac{x \quad \bar{x}}{\sigma} \qquad (1)$$

where: X = annual rainfall; $\bar{X}$ = mean annual rainfall for the study period 1960-2010; σ = standard deviation for annual rainfall for the study period.

REGRESSION MODELS

Regression models are statistical tools used to model the relationship between two or more variables. In this study, linear regression model was adopted. Equation 2 was the simple linear regression equation that was used. Time in years was used as independent variable (X) while annual rainfall was considered the dependent variable (Y). The least square/linear regression model was presented as:

$$Y = a + bX + e \qquad (2)$$

Where: Y = dependent variable (annual rainfall); X = independent variable (time in year); a = constant on Y – intercept; b = regression coefficient; e = error random term

RESULTS AND DISCUSSION FOR OSOGBO RAINFALL CLIMATE FROM 1960-2010

For the study area, the average monthly rainfall varied from 8.32 mm-211.03 mm. Mean maximum monthly rainfall of 449.6mm occurred in August while the highest mean monthly rainfall of 211.03 mm occurred in September as shown in Table 1. Rainfall showed a positive trend which can increase overtime with Kendall's S value of 111 as shown in Table 2. The trend was not statistically significant since the Z_s test statistics of 0.937 was less than 1.96

at 95% significant level as shown in Table 2. The linear regression model obtained was Y = 0.2109X + 110.68 as shown in Table 3. This result showed that the mean monthly precipitation value of 110.68 mm obtained in the linear regression model was very close to the annual monthly rainfall value of 111.3 mm. The analyses of variance (ANOVA) test showed a p-value of 0.324561 which is less than 0.05 at 95% significance level as shown in Table 4. The result showed that the variance in the annual rainfall is not statistically significant.

Table 1. Monthly statistical summary for precipitation for 1960-2010

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	16.58	22.79	85.13	12.13	158.37	181.93	163.08	134.10	211.03	193.48	38.79	8.32
Min	0	0	5.5	24.7	46.7	69.2	40.6	27.9	73.8	73.7	0	-88
Max	118.1	92.9	212.3	248	313.2	307.1	361.7	449.6	378.7	393.1	135.2	52.1
SD	26.75	25.06	44.77	46.26	51.42	55.21	83.19	93.12	67.59	61.90	38.60	20.64
Skew	2.17	1.11	0.59	0.34	0.63	0.05	0.622	1.21	0.40	0.74	1.10	-2.2
Kurtosis	4.90	0.39	0.67	0.24	0.72	-0.64	-0.23	1.45	0.52	1.37	0.16	12.10
CV	1.61	1.10	0.53	3.81	0.32	0.30	0.51	0.69	0.32	0.32	1.00	2.48

Table 2. Mann-Kendall Results of Meteorological Parameters

Variable	Autocorrelation factor	Kendall's S	Z_s	Trend nature	Trend significance
Precipitation	0.068	111	0.937	Positive	No

Table 3 Regression Analysis Results of Meteorological Parameters

Variable	Regression Equation	R^2 (%)	Correlation Coefficient
Precipitation	$Y = 0.2109X + 110.68$	2.0	0.87

Table 4. Variance Analysis for Precipitation

Sample	DF	SS	MS	F	F significant
Regression	1	491.5538	491.5538	0.990287	0.324561
Residual	49	24322.38	496.3752		
Total	50	24813.94			

Where: DF = Degree of freedom; SS = Sum of square; MS = Mean of square; F = F- test statistic; F significant = p-value

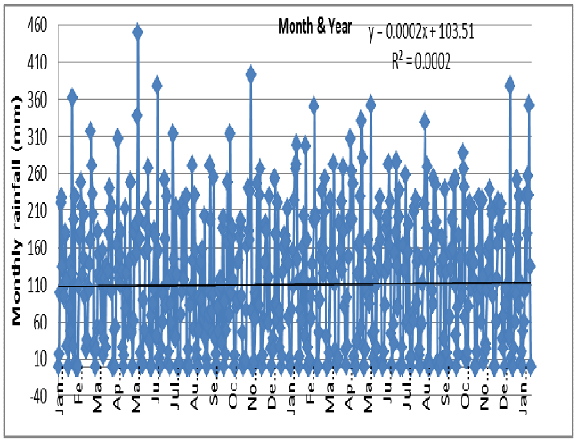

Figure 5. Monthly rainfall between January 1960 to December 2010

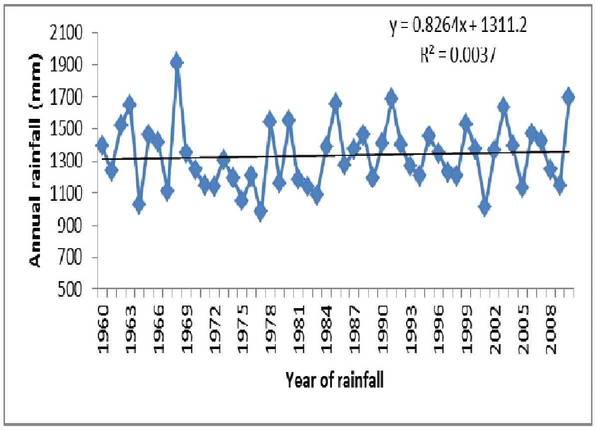

Figure 6. Annual rainfall between 1960-2010

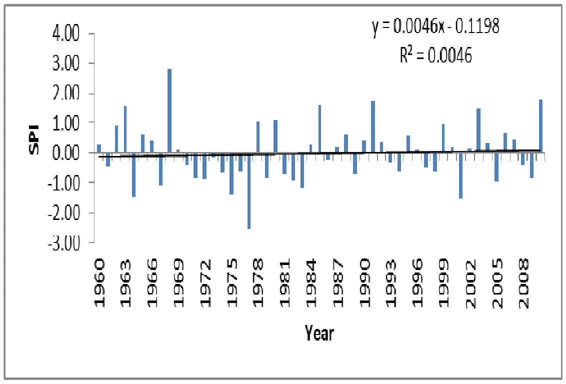

Figure 7. Interannual variation of rainfall using SPI from 1960-2010

Table 5. Standardized Precipitation Index (Mckee et al, 1993)

SPI Range	Range meaning
> +2.0	Extremely wet
+1.5 to +1.99	Very wet
+1.0 to +1.49	Moderately wet
-0.99 to +0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Table 6. Decadal analysis of monthly rainfall based on Annual Contribution Index (ACI)

Decade	ACI Class of rainfall (%)				
	A(0-10)	B (10-15)	C(15-20)	D(20-50)	E (>50)
1960-69	61	23.3	11.7	3.3	-
1970-79	64.1	17.5	11.7	6.7	-
1980-89	60	20	12.5	7.5	-
1990-99	56.7	25.8	13.3	4.2	-
2000-09	60.8	26.7	10	2.5	-
1960-2010	60.6	22.8	12	4.6	

Based on Standard Precipitation Index, the inter-annual variation for the study period and study area is described as near normal since the mean SPI of -0.1198 falls within the range of -0.99 to +0.99 as shown in Table 5. The mean annual rainfall and standard deviation for the study period were 1329.22 mm and 206.96 mm respectively. This results in a rainfall coefficient of variation (CV) of 0.156 which was higher than the CV of 0.050 obtained by Akinsanola and Ogunjobi (2014) for Osogbo for a shorter period of 1971-2000. Based on Australian Bureau of Meteorology (2010), and Hare's (1983) classification, the rainfall variability is low since the CV of 0.156 is less than the index of 0.5 and 20% for low variability and since the CV of 15.6% is less than the 20% for low variability respectively (Table 7).

In addition, decadal analysis of monthly rainfall based on annual contribution index (ACI) showed that the monthly rainfalls can be described as majorly uniform and slightly moderately seasonal since 60.6% of the total monthly rainfalls within the study period have ACI of 0-10% while 22.8% have ACI value of 10-15% (Table 6). Furthermore, decadal ACI analyses of rainfall showed the actual compositional changes that occurred in rainfall in the study area. In the first decade, the monthly rainfall composition was such that 61% belong to class A, 23.3% class B, 11.7% were in Class C while 3.3% belong to Class D. The fifth decade (2000-09) experienced an increase of 4.1% and 0.9% increase in Classes A and B rainfalls and a decrease of 3.3% and 1.7% in Classes C and D rainfalls. In summary, comparison of the first decade (1960-69) and the fifth decade (2000-09) revealed a decrease of 0.2%, 1.7% and 0.8% in Classes A, C and D rainfalls but an increase of 3.4% in Class B rainfall.

Table 7 Rainfall variability index[a] and classification of variation classes[b]

Class	Index[a]	CV (%)	Class[b]
Very high	1.5-2	>30	Highly variable
High	1.25-1.5	20-30	Moderate
Moderate to high	1-1.25	<20	Low
Moderate	0.75-1.0		
Low to moderate	0.5-0.75		
Low	<0.5		

a= Australian Bureau of Meteorology b= Hare (1983)

Table 8 Rainfall classification based on Annual Contribution Index (ACI)

Classification	**ACI[c] (%)**
Irregular	**>50**
Highly seasonal	**20-50**
Seasonal	**15-20**
Moderately seasonal	**10-15**
Uniform	**0-10**

c= Modified classification by Mahmoud et al (2014)

Impacts and Implications of Rainfall Variability on the Design of Road Culverts

Decadal analysis of annual rainfall shown in Figure 8 indicated a reduction of rainfall in the second decade (1970-79) and an increasing trend between the third decade (1980-99) and the fourth decade (1990-99) but a reduction in the fifth decade (2000-09). The decadal annual rainfall that recorded in the third to fifth decade which ranged from 1318.4-1373.75 mm as shown in table 9 and figure 8 were still less than the decadal annual rainfall of 1406.59 mm which occurred in the first decade (1960-69) when the area was largely undeveloped.

Table 9. Graph of mean decadal annual rainfall for Osogbo

S/N	Decade period	Mean annual value (mm)
1	1960-69	1406.59
2	1970-79	1180.03
3	1980-89	1331.07
4	1990-99	1373.75
5	2000-09	1318.4

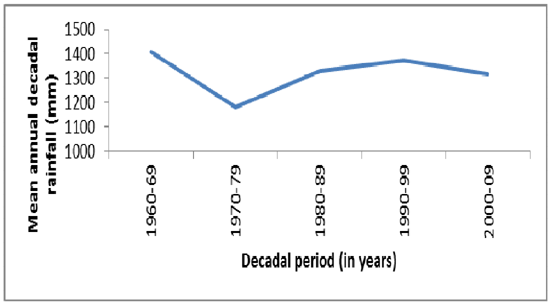

Figure 8 Graph of mean decadal annual rainfall for Osogbo

In addition, the low rainfall variability and uniform rainfall of the study location means that water resources and impacts such as flood in the study area can be easily managed and adequately taken care of since majority of the rainfall (83.4%) are not significantly different from the average mean. However, efforts must be taken to regularly maintain the culverts through regular and periodic desilting. In addition, provision of effective solid waste disposal must be provided by government.

Hydrologic Modelling of Osogbo Watersheds

Hydrologic modeling of Osogbo watersheds was done using Rational Equation method as shown in equation 9. The watersheds/drainage areas covering the locations of the culverts are shown in Figures 9-12.

$$Q = cIA \qquad (3)$$

Where: In American Units, C= dimensionless runoff coefficient, a function of soil surface infiltration conditions, shown in Table 9; I= rainfall intensity, in inches per hour (in/hr); A= drainage area in acres; Q= Flow or discharge, ft^3/s corresponding to 100-year peak flows and in metric units, C = dimensionless runoff coefficient; I= rainfall intensity in mm/hr; A= drainage area in km^2; Q= Flow or discharge in m^3/s

Table 10 Runoff coefficients for African urban centers (USACE, 1994)

Ground cover	Runoff coefficient, c
Lawns	0.05-0.35
Forest	0.05
Cultivated land	0.08-0.41
Meadow	0.1-0.5
Parks, Cemeteries	0.1-0.25
Unimproved areas	0.1-0.3
Pasture	0.12-0.62
Residential areas	0.3-0.75
Business areas	0.5-0.95
Industrial areas	0.5-0.9
Asphalt/Paved Streets	0.7-0.95
Brick Streets	0.7-0.85
Roofs	0.75-0.95
Concrete Streets	0.7-0.95

The rainfall intensity corresponding to a 100-year flood was extrapolated from the mean of the results of IDF curves for Ibadan and Ondo with similar rainfall pattern as shown in Table 11. Time of concentration for Osogbo to facilitate the use of the IDF curves was calculated using Kirpich formula shown in equation 10.

Figure 9. Rasco valley drainage divide

Figure 10 Moye oil valley drainage divide

Figure 11 Nitel Valley drainage divide

Figure 12 Odo-Igbo drainage divide

Table 11: Intensity-duration frequency data (Awokola, 2002)

Intensity duration frequency data for two stations		
Stations	Duration (hr)	Average mean (In/hr)
Ibadan and Ondo	0.2	4.405
	0.4	3.395
	0.7	2.6
	1.0	2.04
	2.0	1.175
	3.0	0.835
	6	0.455
	12	0.235
	24	0.125

Kirpich formula for calculating time of concentration is:

$$T_c = \frac{0.00032\ X\ L^{0.77}}{S^{0.385}} \text{ in metric units} \qquad (4)$$

$$T_c = \frac{0.000128\ X\ L^{0.77}}{S^{0.385}} \text{ in SI units} \qquad (5)$$

Where T_c = time of concentration in hour (hr); L = Maximum length of water travel in metre (m); H = difference in elevation between the remotest point in the drainage basin and the outlet in m; S = surface slope, given by H/L (m/m)

The peak discharge of storm water run-off for Alekuwodo River @ Rasco was obtained as 2225.47 ft^3/s as follows: L = 3073.04ft, H = 1032 - 985= 47 and S = H/L = 47/3073.04 = 0.015

Therefore, the time of concentration, T_c was obtained as 0.7812 hour = 46.87 minutes

Rainfall intensity with duration of 0.7812 hour was extrapolated from table 10 and obtained as 2.45 in/hr. The peak discharge was obtained using the rational formula as:

Q = cIA = 0.75 x 2.45 x 296.73 = 545.24ft^3/sec and when extrapolating to 100-year flood it gave Q = [10/2.45] x 545.24 = 2225.47 ft^3/sec. Therefore, the peak discharge of storm runoff for Rasco river is 2225.47 ft^3/sec. In similar manner, the peak discharges at various culvert locations were obtained.

Hydraulic Modeling of Culverts in the Study Area

Manning's Equation was used for hydraulic modeling to determine Conveyance Capacities of existing culverts. Manning's equation is specified as:

$$Q = \frac{1.486\ A\ R^{2/3} S^{1/2}}{n},$$

that is, $Q = K.\ S^{1/2}$ (6)

Where: Q = flow quantity, cubic feet per second (ft^3/s); K= Full Flow Coefficient = $\frac{1.486\ A\ R^{2/3}}{n}$; n = Manning's roughness coefficient (Table 12); A = cross-sectional area of flow, in square feet (ft^2); R = hydraulic radius in feet (ft); S = Slope of conduit, feet of vertical drop per foot of horizontal distance.

The geometry of investigated existing culverts obtained from field measurements at selected locations in the study area such as Odo-Igbo, Alakewudo @ Sawmill, Alekuwodo River @ Rasco Hall, Moye Oil River, Okooko River at Obate and Nitel Valley are summarized in Table 13. The design criterion specified for this study was as follows:

I. Where $Q_{(Rational)}$ is > $Q_{(Manning's)}$ ===> Peak Flows > Conveyance Capacity, Culvert size is therefore inadequate and needs to be upgraded.

II. Where $Q_{(Rational)}$ is < $Q_{(Manning's)}$ ===> Peak Flows < Conveyance Capacity, Culvert size is therefore adequate and does not need to be upgraded.

The conveyance capacity obtained for the twin-sized boxed culvert located at Rasco hall River was 1173.2 ft^3/sec since it has a K coefficient of 4790, cross sectional area of 31.11ft^2 and manning's n coefficient of 0.012. Comparison with the Storm runoff $Q_{rational}$ of 2224.47 ft^3/s obtained for the same location showed that the box culvert is undersized since it is less than the value for $Q_{rational}$. Summary of the results obtained for all the culverts were summarized in Table 14.

Table 12 Full flow coefficient values for precast concrete box sections (City of Dallas Public Works, 1993)

Box size Span & Rise (Ft)	Area, A (Ft^2)	Hydraulics Radius (Ft)	C = 1.486/ n [A X $R^{2/3}$]		Box size Span and Rise (Ft)	Area, A (Ft^2)	Hydraulic Radius, R (Ft)	C = 1.486/ n [A X $R^{2/3}$]	
			n = 0.012	n = 0.013				n = 0.012	n = 0.013
3 x 2	5.78	0.63	524	484	9 x 5	43.88	1.67	7060	7070
3 x 3	8.78	0.78	923	852	9 x 6	52.88	1.87	9950	9180
4 x 2	7.65	0.69	743	686	9 x 7	61.88	2.05	12400	11400
4 x 3	11.65	0.90	1340	1240	9 x 8	70.88	2.20	14800	13700
4 x 4	15.65	1.04	1990	1840	9 x 9	79.88	2.33	17400	16100
5 x 3	14.50	0.98	1770	1630	10 x 5	48.61	1.73	8690	8020
5 x 4	19.50	1.16	2660	2460	10 x 6	58.61	1.95	11300	10462
5 x 5	24.50	1.30	3620	3340	10 x 7	68.61	2.14	14100	1300
6 x 3	17.32	1.04	2200	2030	10 x 8	78.61	2.31	17000	15700
6 x 4	23.32	1.25	3350	3100	10 x 9	88.61	2.46	20000	18500
6 x 5	29.32	1.42	4590	4240	10 x 10	98.61	2.59	23000	21300
6 x 6	35.32	1.56	5880	5430	11 x 4	42.32	1.52	6930	6390
7 x 4	27.11	1.33	4050	3740	11 x 6	64.32	2.02	12730	11700
7 x 5	34.11	1.52	5590	5160	11 x 8	86.32	2.41	19200	17700
7 x 6	41.11	1.68	7200	6650	11 x 10	108.32	2.72	26100	24100

Table 13 Existing culvert geometry for selected location

S/N	**Name of River**	**Height (ft)**	**Width (ft)**	**Length (ft)**	**Culvert Type**
1	Odo Igbo River	4	11.48	59.71	Box
2	Alakewudo (Sawmill)	4.5	26.34	53.14	Box
3	Alakewudo (beside Best	4.1	26.40	48.22	Box
4	Rasco Hall River	4	16.40	33.79	Box (twin-size)
5	Moye Oil River	4.2	13.12	61.02	Box
6	Okooko (at Obate)	7.5	37.48	47.84	Box
7	Nitel	5	10.24	59.03	Box

Table 14 Summary of Peak Discharge and Culvert Capacities for Different locations in the Study Area with recommendations

S/N	Location of Culvert	Peak Discharge Q=cIA (ft^3/s)	Existing Culvert Capacity Q = $K.S^{1/2}$(ft^3/s)	Existing Culvert Size	Recommendations
1	Odo-Igbo	1379.62	1266.50	11 x 4	Existing culvert size is undersized. Culvert capacity is grossly inadequate and upgrade required
2	Rasco Stream	2225.0	1173.2	2 (8 X 4)	Existing culvert is grossly undersized. Culvert capacity is inadequate and upgrade is required
3	Alekuwodo (Sambest Bookshop)	708	792.93	12 x 4	Culvert capacity is marginally adequate. Coveyance capacity should remain unchanged. Regular maintenance is required.
4	Alekuwodo (Sawmill)	3615	2463.2	2 (8 x 7)	Existing culvert is grossly undersized. Culvert capacity is grossly inadequate and upgrade is required.
5	Moye Oil	2218	774.36	12x 4	Existing culvert is grossly inadequate. Serious culvert upgrade is required.
6	Okooko	1464.22	5799.6	3 (10 x 7)	Conveyance capacity for this culvert is very adequate
7	Nitel	702.25	919.40	10 x 5	Conveyance capacity for this culvert is adequate. Regular maintenance is required.

Hec-Ras modeling of the Rasco stream watershed (Figures 13-14) similarly showed the inadequacy of the culvert as the channel and floodplains were inundated with about 7ft of flood water.

HEC-RAS MODELLING OF ALEKUWODO STREAM @ RASCO WATERSHED

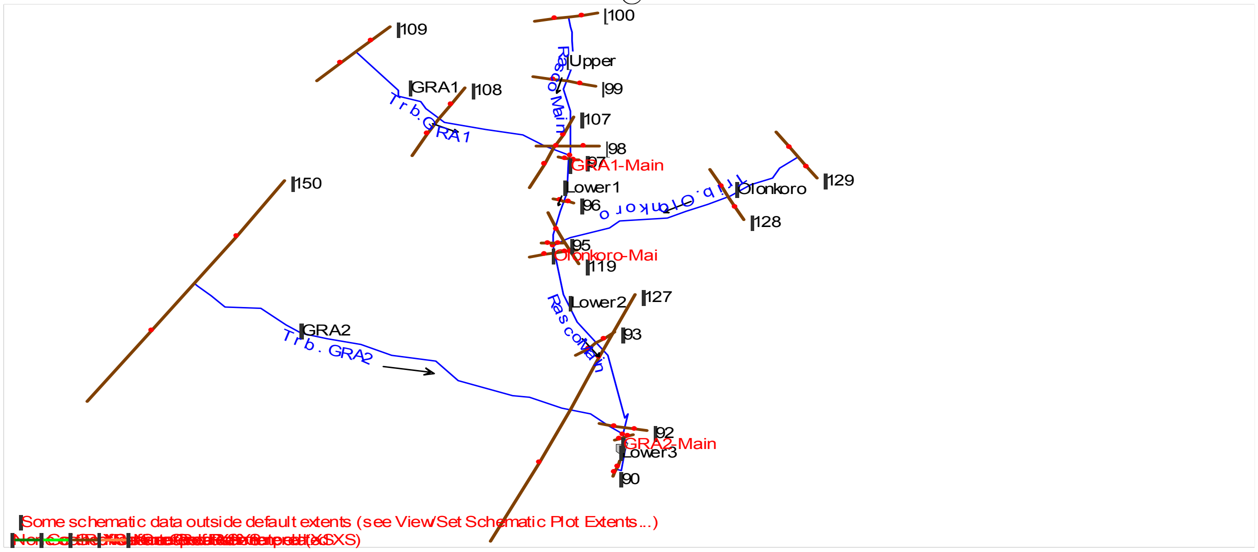

Figure 13 Rasco River Schematics using Hec-Ras

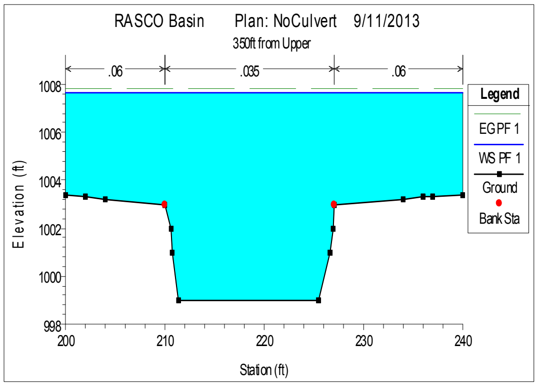

Figure 14 Hec-Ras Output for 100-yr Water Surface Profiles at Rasco River

CONCLUSION AND RECOMMENDATIONS

The incessant flooding in Osogbo can be adequately curtailed through construction of properly planned and well designed drainage systems factoring climate change impacts. Government should engage certified engineering professionals in such capital-intensive projects to ensure they function effectively throughout their design life. In addition, it is recommended that upgrade should be provided for culverts that are grossly inadequate while regular desilting maintenance should be provided for culverts that are both adequate and marginally adequate. Furthermore, culvert rehabilitation/construction should precede any future road expansion and rehabilitation exercise while the culverts should be properly analysed and designed to meet hydrologic demands of past, present and future climate scenarios.

LIMITATIONS OF STUDY

The study was limited to the rainfall data available for analyzing climate change/variability of the study area. In addition, influence of natural factors such as soil erosion, as well as anthropogenic factors such as illegal solid waste disposal on conveyance capacity were not taken into consideration owing to paucity of data. It will be valuable if future research can take cognizance of these additional factors.

REFERENCES

Akinsanola A.A. and Ogunjobi K.O. 2014. Analysis of rainfall and temperature variability over Nigeria. Global J. of Human Social Science-B. Geography, D=Geosciences, Environmental Disaster 14 (3) Version 1

Andersson-Skold, Y., Suer P., Bergman, R., Helgesson, H. 2014. Sustainable decisions on the agenda-a decision support tool and its application on climate change adaptation. Local Environment: Int. J. of Justice & Sustainability http://dx.doi.org/10.1080/13549839.2014.922531

Australian Bureau of Metrology, 2010. Rainfall variability in Australia http: www.bom.gov.au/climate/data/index.shtml. Accessed on March 1, 2015

Awokola, O. S. 2002. College of Environmental Resources Management, Department of Water Resources Management and Agricultural Meteorology, University of Agriculture, Abeokuta.

Babatolu, J. S. 1998. Climate Change and its Implications for Water Supply in the Niger River Basin Development Authority Area of Nigeria. A P.hD Thesis, Department of Geography and Environmental Management, University of Ilorin, Ilorin, Nigeria.

City of Dallas Public Works 1993. Drainage Design Manual

Doll P., Jimenez-Cisneros B., Oki T., Arnell N.W., Benito G., Cogley J.G., Jiang T., Kundewicz Z.W., Nwakalila S., Nishijima A. 2015. Integrating risks of climate change into water management, Hydrological Sciences Journal, 60:1, 4-13 http://dx.doi.org/10.1080/02626667.2014.967250

European Commission 2013. Adapting infrastructure to climate change. Commission staff final working document. Brussels

Fadare, S. O. and Olawuni, P. O. 2008. Domestic Water Supply and Health of Households in the Three Residential Densities in Osogbo, Osun State, Nigeria, Ethiopian Journal of Environmental Studies and Management. 1(2): 35-43.

Hare, F.K., 1983. Climate and desertification. Revised analysis (WMO-UNDP) WCP-44, pps 5-20, Geneva, Switzerland

Hess C., Anderson S., Cotuila L., Skinner J., Toulmin C. 2013. Managing the boom and bust. Supporting climatic resilient livelihoods in the Sahel. Int. Institute for Environment & Development, UK

Kinninmonth S., Berdsten A., Bodin O. 2015. Closing the collaboration gap: Aligning social and ecological connectivity for better management of interconnected wetlands. AMBIO (Suppl. 1.). doi:10.1007/s13280-014-0605-9

Kundewicz Z.W., Mata L.J., Arnell N.W., Doll P., Jimenez B., Miller K., Oki T., Sen Z., Shiklomanov I. 2013. Hydrological Sciences, 53 (1): 3-10 http://dx.doi.org/10.1623/hysj.53.1.3

Mahmoud W.H., Elajib N.A., Gaese H, Heinrich J., 2014. Rainfall conditions and rainwater harvesting potential in the urban area of Khartoum. Resources, Conservation and Recycling. 91, 84-99

McKee T.B., Doesken N.J., Kleist J. 1993. The relationship of drought frequency and duration to time scales. 8th Conf. on Appld. Climatology, 179-184, Jan. 17-22, Anaheim, California

National Bureau of Statistics, 2010. Annual Abstract of Statistics, 2010. NBS, Federal Republic of Nigeria

Ojoye, S. 2012. Climate Change Impact on Water Resources and Adaptation Strategies in the Sudano-Sahelian Ecological Zone of Nigeria. A Ph.D Thesis, Department of Geography and Environmental Management, University of Ilorin, Ilorin, Nigeria.

Raziel, T. 2008. Investigation of Annual Precipitation Trends in Homogeneous Precipitation Sub-Divisions of Western Iran. BALWOIS Ohrid, Macedonia Republic pp. 1-7

U.S. Army Corps of Engineers. 1994. Hydraulic design of flood control channels. Engineer Manual 1110-2-1601, Change 1, 30 June 1994. Washington, DC.